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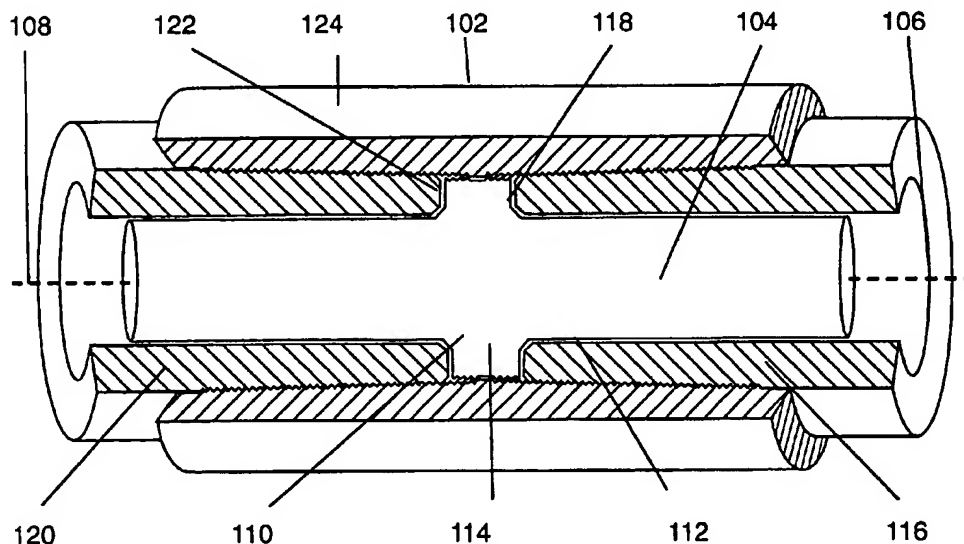
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**(54) Title:** PLUG FOR TUBULARS



**(57) Abstract:** A molten metal plug (104) which expands upon solidification can be used to form a pressure resistant seal in a tubular (102) such as is used in oil and gas exploration and production.

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## DESCRIPTION

### PLUG FOR TUBULARS

#### 5      **Technical Field**

In one aspect, this invention relates to a plug for tubulars. In another aspect, this invention relates to a pipe plug that is formed in the pipe. In yet another aspect, this invention relates to a pipe plug that is particularly useful for forming barriers downhole, such as downhole in oil and gas wells. In yet another aspect, this invention relates to a method for isolating  
10      pipe sections from each other. In a further aspect, this invention relates to a method for isolating a subterranean formation from a section of a pipe passing through the formation. In a further aspect, this invention relates to isolating one subterranean formation from another subterranean formation.

#### 15      **Background Art**

Pressure seals to isolate formations in a well are currently performed through the use of bridge mechanical plugs. It can be necessary to isolate formations, for example, where it is desired to flow fluid through one set of perforation in the well casing but not another set. This can be needed, for example, in fracturing operations. Isolation can also be needed,  
20      for example, in offshore situations where a zone is to be abandoned, and a re-completion to an upper zone (below the packer) is expected.

The bridge plugs currently used for such applications are mechanical devices that grab the casing walls by the use of slips, and isolate the pressure through the use of elastomers (that energize when the seals are deployed). For these types of bridge plugs to work under high  
25      differential pressures, the bridge plug body must have an outside diameter (OD) very close to the casing inside diameter (ID). Bridge plugs that are of small OD but expand to a large OD would be very valuable to the industry. This is because they could be run through the existing tubing and expanded to set in the casing. This operation could be accomplished  
30      without pulling the tubing, which is a very expensive operation. Unfortunately, these types of expandable mechanical bridge plugs cannot reliably withstand differential pressures of

more than 3,500 psi (differential pressures), and differential pressures of between 3,500 and 15,000 psi are normally encountered.

5 A pressure seal that could be introduced through narrow passages and form a reliable seal would be very desirable.

A pressure seal that could reliably withstand a differential pressure of 3500 psi would be very desirable.

10 A pressure seal that has an OD which can conform to irregularities in its confining walls would be also very desirable.

15 Another problem encountered in the oil and gas industry is the pressurization of the annular space between two casing strings in a well. Where the pressurization reaches the surface, it must be removed.

A technique to isolate the uphole portion of the annulus from fluid pressure in downhole portions of the annulus would be very desirable.

20 Other needs in the industry which can be met by the invention include:  
An ability to pressure seal lateral junctions on horizontal wells;  
The ability to plug open perforations that produce unwanted production in a well;  
The ability to repair corroded, worn or damaged well casing;  
The ability to control pressure in well control situations and blow-outs.

25

### **Disclosure of Invention**

In one embodiment of the invention, there is provided a tubing containing a plug which was cast in the tubing.

30 In another embodiment of the invention, there is provided a method for isolating a first volume from a second volume by positioning a molten mass of material in a passage

between the two volumes and permitting the mass to solidify and cool so as to form a highly pressure resistant seal across the passage.

Another embodiment of the invention provides a packer apparatus which is well suited to the practice of the above embodiments. The apparatus is provided in the form of a container having a generally cylindrical sidewall and a bottom end closure. A mass of soldering composition is positioned in the container. An electrical resistance heating element is positioned adjacent to the mass of soldering composition. The electrical heating element can be activated to melt the soldering composition, and then deactivated to permit the soldering composition to solidify and seal. When removal of the packer is desired, the electrical heating element can be reactivated to remelt the solder and release the packer.

#### **Brief Description of Drawings**

Figure 1 is a sectional view illustrating the invention being employed in a standard pipe connection.

Figure 2 is a sectional view illustrating the invention being employed in a premium pipe connection.

Figures 3-5 schematically illustrate a method of the invention being employed to seal a tubing annulus.

Figure 6 illustrates schematically the use of one embodiment of the invention.

Figure 7 illustrates schematically the use of another embodiment of the invention.

Figure 8 illustrates, in cross section and partly schematically, a packer tool in accordance with an embodiment of the invention.

**Best Mode for Carrying out the Invention**

In the method of one embodiment of the invention, a molten mass of material is positioned in a passage and permitted to solidify. If desired, the method can be employed to form a highly pressure resistant seal between a first inside portion of a tubing and a second inside portion of the tubing.

Materials suitable for use in this embodiment of the invention generally include most any material that will solidify under locally ambient conditions around the tubing and form a plug having sufficient strength and bond to withstand the pressure differential across the plug. Preferably, the plug forms a tight mechanical pressure seal. This can be accomplished by either or both of selecting a molten mass of metal which expands as it solidifies and/or heating the tubing sufficiently so that it will diametrically shrink adequately to form the tight mechanical pressure seal as it cools. The former can be facilitated by selecting a soldering composition which contains least 10 parts per hundred, preferably at least 30 parts per hundred, and most preferably, at least 50 parts per hundred, of Bismuth. The second can be facilitated by heating the tubing to relatively high temperatures, such as in the range of 600-1100° F, and, if desired, employing a brazing composition to form the plug.

For downhole applications, locally ambient temperatures can range from about -40 to about 1,000 °F (or higher, but such temperatures are not compatible with desirable liquid hydrocarbon products). Generally, downhole temperatures will range from about 32 °F to about 700 °F and will often be in the range of from about 100 °F to about 650 °F. Locally ambient pressures can range from 14.7 psi to 20,000 psi (or higher), but will generally range from about 14.7 to 15,000 psi and are usually in the range of from 14.7 to 10,000 psi.

Suitable materials will generally comprise a high percentage, generally in excess of 90% by weight of metals and will exhibit a melting point of less than 1100 °F, generally in the range of 100 to 1000 °F. Generally speaking, it is preferable that the materials be relatively soft, so that they can be easily drilled out. Soldering compositions are generally

suitable for most applications. Most suitable soldering compositions are metal alloys. As noted above, it is also desirable to have materials that expand when changing from a molten state to a solid state.

5 Preferred solders for use at ambient temperatures in the range of 150-600 °F can comprise chiefly bismuth with optional lead, tin, and silver. Some examples from the Handbook of Chemistry and Physics, 54th edition, 1973-1974 (CRC Press, Cleveland, Ohio) include

	25 Pb/25 Sn/50 Bi	(266 °F liquidus temperature),
10	25 Pb/50 Sn/25 Bi	(336 °F liquidus temperature)
	50 Pb/37.5 Sn/12.5 Bi	(374 °F liquidus temperature)
	60 Pb/40 Sn	(460 °F/361 °F liquidus/solidus temps) (AWS-ASTM classification 40A)
	85 Pb/15 Sn	(550 °F/440 °F liquidus/solidus temps) (AWS-ASTM classification 15B)
15	97.5 Pb/2.3-2.7 Ag	(588 °F/588 °F liquidus/solidus temps) (AWS-ASTM classification 1.5S)

In the table just given, constituents present at less than 1 part per hundred are not listed.

20

For applications in the 600-1000 °F range, preferred solders comprise chiefly aluminum or magnesium-containing brazing materials. Examples (from CRC) include

	11.0-13.0 Al/4.5-5.5 Zn/bal. Mg.
25	(liquidus/solidus temps 1050/770 °F) (AWS-ASTM classification 1.5S)

	8.3-9.3 Al/1.7-2.3 Zn/bal. Mg
	(liquidus/solidus temps 1110/830 °F) (AWS-ASTM classification BMg-1)

30	3.3-4.7 Cu/9.3-10.7 Si/bal. Al
	(liquidus/solidus temps 1085/970 °F) (AWS-ASTM classification BAISi-3)

In the table just given, constituents present at less than 1 part per hundred are not listed.

US Patent 4,561,300 discloses a wide range of suitable materials having melting points between 76°C and 351°C. Examples include

5

	COMPOSITION	melting point ( °C)
	Bi 48.5, In 41.5, Cd 10	076
	In 52.34, Bi 47.66	088
10	Bi 52.5, Pb 32, Sn 15.5	096
	Bi 54, Sn 26, Cd 20	103
	Bi 67, In 33	110
	In 52, Sn 48	118
	Bi 56.5, Pb 43.5	126
15	Bi 56, Sn 40, Zn 4	133
	Bi 60, Sn 40	139
	Bi 60, Cd 40	147
	Sn 68.35, Cd 29.25, Zn 2.4	159
	Sn 71, Pb 24, Zn 5	170
20	Sn 67.75, Cd 32.25	175
	Sn 62.5, Pb 36.15	180
	Sn 61.9, Pb 38.1	184
	Sn 91, Zn 9	198
	Sn 91, Mg 9	205
25	Sn 95.8, Ag 3.5, Cu 0.7	218
	Sn 96.5, Ag 3.5	222
	Sn 99.5, Al 0.5	229
	Sn	231
	Sn 99.41, Cu 0.32, Al 0.27	234

7

	Pb 79.7, Cd 17.7, Sb 2.6	239
	Pb 84, Sb 12, Sn 4	243
	Pb 82.6, Cd 17.4	249
	Pb 88.9, Sb 11.1	253
5	Bi 97.3, Zn 2.7	256
	Bi 97.5, Ag 2.5	263
	Cd 82.6, Zn 17.4	265
	Bi	273
	Pb 91, Sb 4.68, Cd 4.32	276
10	Ga 92, Mg 18	285
	Cd 92.45, Sb 7.55	294
	Pb 96.97, Ag 2.20, Sb 0.83	301
	Pb 97.5, Ag 2.5	303
	Pb 97.55, Ag 1.75, Sn 0.7	311
15	Pb 98.1, Sb 1, Zn 0.9	315
	Pb 97.4, Sn 2.6	320
	Pb 98.76, Sn 1.24	325
	Pb	329
	Zn 92.97, Al 4.08, Mg 2.95	344
20	Te 70.6, Ag 29.4	351

Other suitable materials having a yield temperature over the range of 105 °F to 357 °F are commercially available from, for example, Cerro Metal Products Co. of Belefonte, PA. Examples include:

25

COMPOSITION	yield temperature (°F)
42.91 Bi/21.70 Pb/7.97 Sn/5.06 Cd/18.33 In/4.00 Hg	105
49.0 Bi/18.0 Pb/12.00 Sn/21.00 In	138



	50.00 Bi/26.70 Pb/13.30 Sn/10.00 Cd	158
	50.31 Bi/39.2 Pb/1.5 Sn/7.99 Cd/1.00 In	181
	56.00 Bi/22.00 Pb/22.00 Sn	205
	33.33 Bi/33.34 Pb/33.33 Sn	232
5	25.50 Bi/14.5 Pb/60.00 Sn	270
	20.00 Bi/50.00 Pb/30.00 Sn	293
	10.00 Bi/40.00 Pb/50.00 Sn	324
	95.00 Bi/5.00 Sn	357

10 In the oil and gas industry, the invention will often be employed to form a seal in a tubing that extends generally downwardly into the earth. It is generally first necessary to remove standing liquids from the location where the plug is desired. This can be done by the injection of gas at the wellhead. For example, the well can be bullheaded with nitrogen and the well liquids, if any, can be displaced to the perforations. Once the liquids have

15 been removed, the invention can be carried out by positioning a platform for the molten metal in the tubing and forming a pool of the molten metal on the platform. A petal basket will provide a suitable platform. In a production tubing, the platform is preferably positioned slightly below a joint in the tubing, so that the molten material will flow into recesses which typically exist in the vicinity of the joints to more tightly secure the plug.

20

In an annulus between the production tubing and the casing, the platform can be provided by the upper surface of the cement which fills the lower portion of the annulus. Preferably, a column of particulate material, such as sand or cement, is positioned on top of the molten material, to urge the molten material into the recesses. The column of particulate material

25 can be positioned with a bailer.

25

The molten pool can be formed by a variety of techniques. For example, it can simply be poured onto the platform in liquid or molten form, such as from an insulated wire-line bailing tool or from an insulated (or heated) tubing which empties near the platform.

30 Alternatively, electrical resistance heating could be employed to melt the material in situ. For example, the material could be conveyed into position in particle form, and melted in

30

situ, such as by an electrical heating element. Another option would be to employ a solid bar of the material which contains an electrical heating element and melting the bar to provide the molten pool. The electrical heating element could be in the form of a probe which can be lowered into position using an oil field electric wireline unit. The probe can then be heated to melt the material and can then be removed prior to permitting the molten material to solidify.

In another embodiment of the invention, a self-contained unit containing the material to be melted can be placed, used, and retrieved as desired. In this embodiment, a soldering composition which expands upon solidification is used. A container of the soldering composition is lowered into a desired position in the tubing. The container has a bottom end closure which forms the platform. The pool of molten material is formed in the container. Preferably, the container has a generally cylindrical sidewall. The molten material expands as it solidifies so as to urge at least a portion of the sidewall of the container into sealing relationship with the inside surface of the tubing. The sidewall is preferably at least partially formed from a synthetic polymer material, such as a high temperature rubber, or a ductile metal, such as copper or aluminum.

Where it is desired to isolate sections of an annulus, such as between a production tubing and a casing, the platform will generally be positioned so as to extend across the annulus between the outer tubing and the inner tubing. This application can be of high importance when attempting to remove pressure (as dictated by many government regulations) from any annular space at the surface of a well. Most of this pressure comes from faulty cement that is meant to form a seal to keep formation pressure from entering the annular space. Particles of the selected material could be positioned on the platform and melted in situ, such as by the application of heat through the wall of the inner tubing by an electrical heating element positioned on the inside of the inner tubing at a longitudinal position alongside the material to be melted. In this application, the top of the cement may form the platform, and the particles simply poured into the annular space. Preferably, the pool is formed against a joint in the tubing so that flow of the molten material into the recesses or will form itself into a shoulder or flange to form a metal to metal seal that will act as a

barrier to unwanted pressure and production. This technique can also be applied to other leaks in the well annulus, such as top liner leaks.

Referring now to Figures 1 and 2, reference call outs in Figure 1 are in the 100 series, reference call outs in Figure 2 are in the 200 series, and reference call outs in Figures 3-5 are in the 300 series. These Figures show a tubing 102, 202, 302 containing a plug 104, 204, 304 which was cast in the tubing.

The tubing is almost always formed from steel and in the oil and gas upstream business is usually in the form of a tubing string. The plug is usually formed from metal solder and forms a seal across the passage defined by the tubing.

Referring now to Figures 1 and 2, the tubing is formed from a sidewall having an inside surface 106, 206 and a longitudinal axis 208, 208. The inside surface of the tubing defines at least one recess 110, 210 leading away from the longitudinal axis. The plug is positioned so that metal extends into the recess.

The inside surface 106, 206 of the tubing is preferably generally cylindrically shaped. The plug 104, 204 has an outside surface 112, 212 which conforms to the generally cylindrical inside surface of the tubing, and at least one generally radially extending protrusion 114, 214 which conforms to the inside portion of the tubing which defines the recess.

In the illustrated embodiments, the tubing is formed from a first pipe section 116, 216 having a first end 118, 218, and a second pipe section 120, 220 having a first end 122, 222. A collar 124, 224 joins the first pipe section to the second pipe section with the first end of the first pipe section facing the first end of the second pipe section. The recess 110, 210 is annularly shaped and is formed between the first end of first pipe section and the first end of the second pipe section. The plug is cast so that metal has flowed into the annular recess and formed a generally radially outwardly extending flange on the plug.

In Figure 2, the first pipe section has a first portion having a first diameter adjacent to the first end and a second portion having a second diameter which is larger than the first diameter which is spaced apart from the first end. The second pipe section is reciprocally shaped. The plug has a first end which is positioned in the second portion of the first section and a second end which is positioned in the second portion of the second section. The plug thus effectively has a mid-flange and two end flanges and can only be displaced after its destruction.

In Figures 3-5, a second pipe 330 is positioned inside of the pipe 302 to define an annulus 332. The pipe 302 is an outside pipe and the second pipe 330 is an inside pipe. The plug 304 is positioned in the annulus 332. The inside pipe and the outside pipe extend downwardly into the earth and generally communicate with an oil or gas reservoir formation 334. A lower portion 336 of the annulus is filled with a cementitious material. Sometimes, the cementitious material fails, (see fracture 338) permitting fluid flow from the reservoir to the wellhead via the annulus. In accordance with the invention, the plug 304 is positioned above the cementitious material. Preferably, the plug rests on the top of the cementitious material and seals an upper portion 340 of the annulus from the lower portion.

In the sequence shown by Figures 3-5, the plug is formed in situ by evacuating the tubing of fluids such as by nitrogen pressurization and positioning a mass 340 of beaded, pelleted or other particle form soldering composition on the upper surface 342 of the cement 336. A heater 344 is suspended in the inner tubing 330 adjacent the mass 340 on an electric wireline 346. The heater is activated to melt the mass and form the plug as shown in Figure 5.

In Figure 6, a tubing 602 extends downwardly into the earth into a fluid production zone 604. The tubing has a section 606 which is perforated to define passages 608 which lead from the inside to the outside of the pipe, and the plug 610 is positioned in the perforated section of the pipe. The plurality of perforations form recesses in the generally cylindrical inside surface of the pipe.

The plug has a plurality of protrusions 612 which extend into the perforations to isolate the inside of the pipe from the outside of the pipe. If necessary, the perforations can be sealed with balls from within the production line or backed up with sand in the annulus to facilitate obtaining a tight seal.

5

In Figure 7, a tubing 702 extends downwardly into the earth into a fluid production zone 704. The tubing has a section 706 which is perforated to define recesses 708 which may be perforations as illustrated which lead from the inside to the outside of the pipe, or simply corrosion pitting or a mechanically damaged section of the tubing, and the plug 710 is positioned in the section 706 of the tubing. The plug has a plurality of radially outwardly extending protrusions 712 which extend into the recesses so that it is securely fastened in the tubing. A passage 714 has been drilled longitudinally through the plug 710, so that the plug forms a tubularly shaped repair body. If desired, the tubularly shaped repair body can be formed from a brazing material for greater strength.

10

15

With reference to Figure 8, a packer apparatus 850 is provided in the form of a container having a generally cylindrical sidewall 852 and a bottom end closure 854. A mass 856 of soldering composition is positioned in the container. An electrical resistance heating element 858 is positioned adjacent to the mass of soldering composition. The electrical heating element can be activated via line 860 to melt the soldering composition, and then deactivated to permit the soldering composition to solidify and seal. If desired or necessary, the soldering composition can be melted prior to insertion into the wellbore. When removal of the packer is desired, the electrical heating element can be reactivated to melt the solder and release the packer.

20

25

The sidewall 852 of the container is preferably formed from an elastomeric material such as a high temperature resistant synthetic rubber or a thin-walled ductile metal such as copper or aluminum. The mass of soldering composition is preferably formed from a material which expands in volume as it solidifies from liquid to solid. Preferably, the mass of soldering composition expands in volume in the range of 0.1 percent to 10 percent as

30

it solidifies. A soldering composition which contains at least 10 parts per hundred of Bismuth is expected to give good service.

5 In the illustrated embodiment, a means 862, such as a pipe or running tool, is attached to the container for lowering the container into the wellbore. The line 860 attached to the heating element can be for connecting the heating element to a source of electrical power adequate to melt the soldering composition as well as for removing the heating element (and connecting line) from the wellbore for subsequent operations.

10 While certain preferred embodiments of the invention have been described herein, the invention is not to be construed as being so limited, except to the extent that such limitations are found in the claims.

**Claims**

What is claimed is:

- 5        1. Apparatus comprising  
a tubing containing a plug which was cast in the tubing.
2. Apparatus as in claim 1 wherein  
the tubing is formed from steel, and  
10       the plug is formed from metal solder which has a melting point of less than 1100 °F and  
forms a seal across the tubing.
3. Apparatus as in claim 1 wherein  
the steel tubing is formed from a sidewall having an inside surface and a longitudinal axis,  
15       the inside surface defines at least one recess leading away from the longitudinal axis, and  
the plug is positioned so that metal extends into the recess.
4. Apparatus as in claim 3 wherein  
the inside surface of the tubing is generally cylindrically shaped, and  
20       the plug has an outside surface which conforms to the generally cylindrical inside surface  
of the tubing, and at least one generally radially extending protrusion which conforms to  
the inside portion of the tubing which defines the recess.
5. Apparatus as in claim 3 wherein  
25       the tubing extends downwardly into the earth and into a fluid production zone,  
and the tubing has a section which is perforated to define passages which lead from the  
inside to the outside of the tubing,  
and the plug is positioned in the perforated section of the tubing.
- 30       6. Apparatus as in claim 2 further comprising  
a second tubing positioned inside of the tubing to define an annulus,

wherein the tubing is an outside tubing and the second tubing is an inside tubing, and wherein the plug is positioned in the annulus.

7. Apparatus as in claim 6 wherein

5 the inside tubing and the outside tubing extend downwardly into the earth, a lower portion of the annulus is filled with a cementitious material, and the plug is positioned above the cementitious material.

8. Apparatus as in claim 7 wherein

10 the plug seals an upper portion of the annulus from a lower portion of the annulus.

9. Apparatus as in claim 3

wherein the recess in the generally cylindrical sidewall is formed by corrosion or mechanical damage, and

15 a passage has been drilled longitudinally through the plug, so that the plug forms a tubularly shaped repair body.

10. Apparatus as in claim 3

20 wherein the recess in the generally cylindrical sidewall is formed by a perforation, and a passage has been drilled longitudinally through the plug, so that the plug seals off the perforation.

11. A method for isolating a first volume from a second volume by positioning a molten mass of material in a passage between the two volumes and permitting the mass to solidify  
25 and cool so as to form a highly pressure resistant seal across the passage.

12. A method as in claim 11 wherein the first volume is inside of a tubing and the second volume is adjacent to the first volume.



13. A method as in claim 12 further comprising positioning a molten mass of material between the first volume and the second volume as to isolate the first volume from the second volume when it solidifies, and  
5 permitting the molten mass of material to solidify and cool so as to form a highly pressure resistant seal between the first volume and the second volume.

14. A method as in claim 13 wherein the first volume and the second volume are adjacent volumes inside of the same tubing, wherein the molten mass of metal expands as it solidifies to form a tight mechanical pressure seal.

15. A method as in claim 14 wherein the molten mass of metal comprises a soldering composition.

16. A method as in claim 15 wherein the soldering composition contains at least 10 parts per hundred of Bismuth.

17. A method as in claim 14 wherein the tubing extends generally downwardly into the earth, said method further comprising  
20 positioning a platform for the molten metal in the tubing, and forming a pool of the molten metal on the platform.

18. A method as in claim 17 wherein the platform extends across an annulus between an outer tubing and an inner tubing.

19. A method as in claim 17 further comprising  
25 lowering a container of the soldering composition into a desired position in the tubing, wherein the container has a bottom end closure which forms the platform, and forming the pool of molten material in the container.

20. A method as in claim 19 wherein  
30 the container has a generally cylindrical sidewall; and

the molten material expands as it solidifies,  
so as to urge the sidewall of the container into sealing relationship with the inside surface  
of the tubing.

5        21. Apparatus comprising  
a container formed from a generally cylindrical sidewall and a bottom end closure;  
a mass of soldering composition in the container; and  
an electrical resistance heating element positioned adjacent to the mass of soldering  
composition.

10       22. Apparatus as in claim 21 wherein  
the mass of soldering composition is formed from a material which expands in volume as  
it solidifies from liquid to solid.

15       23. Apparatus as in claim 21 wherein  
the mass of soldering composition expands in volume in the range of 0.1 percent to 10  
percent as it solidifies.

20       24. Apparatus as in claim 21 wherein  
the mass of soldering composition contains at least 10 parts per hundred of Bismuth.

25       25. Apparatus as in claim 21 wherein  
the sidewall of the container is formed from an elastomeric material.

Fig. 1

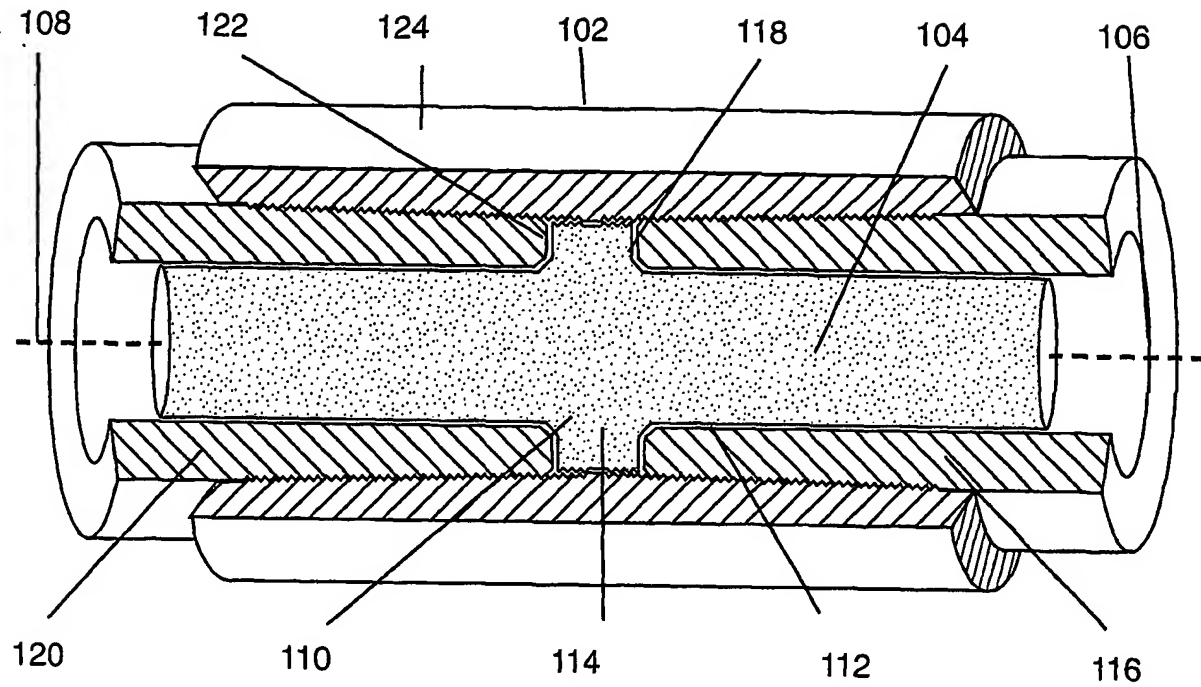


Fig. 2

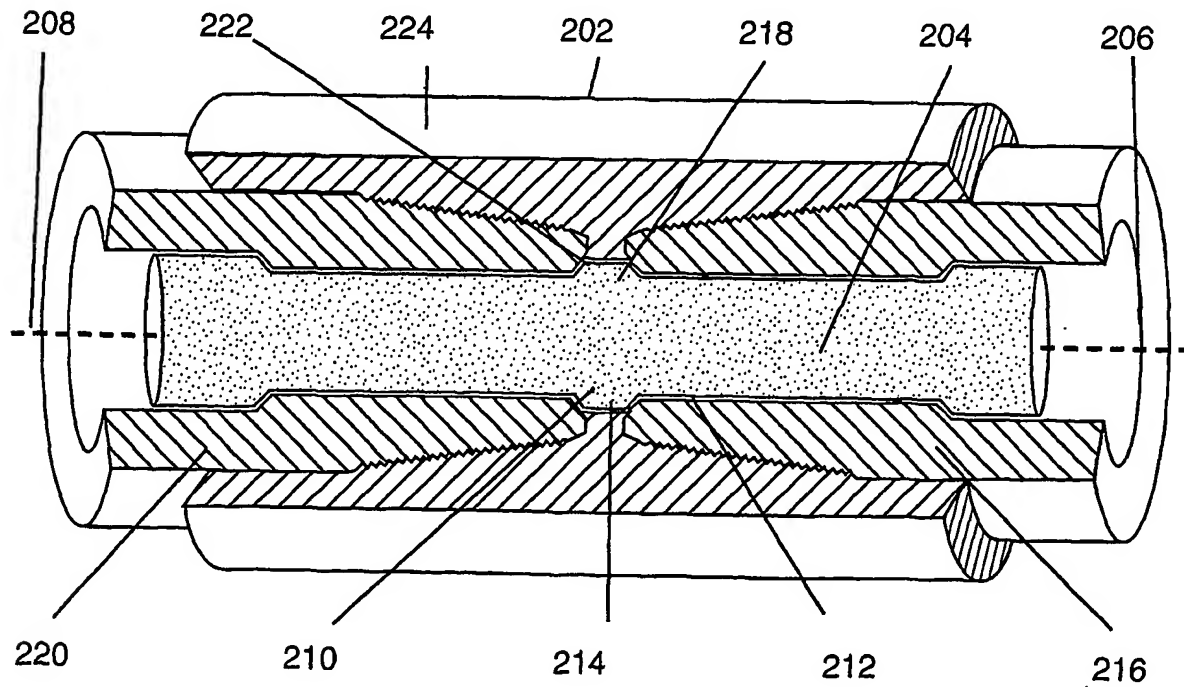


Fig. 3

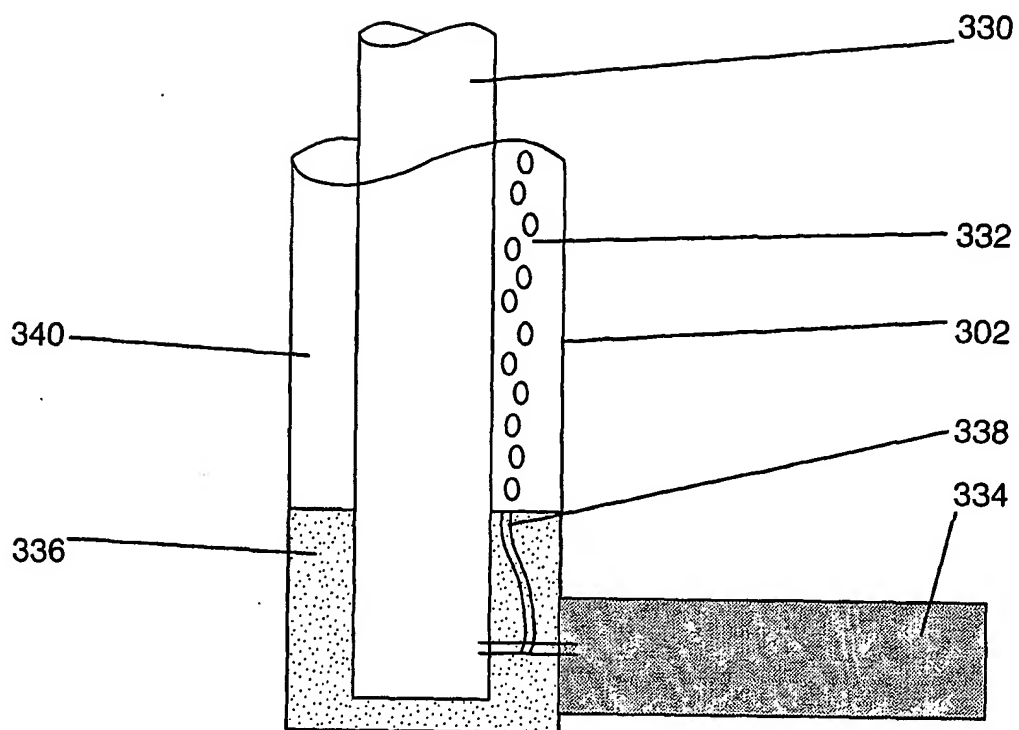


Fig. 4

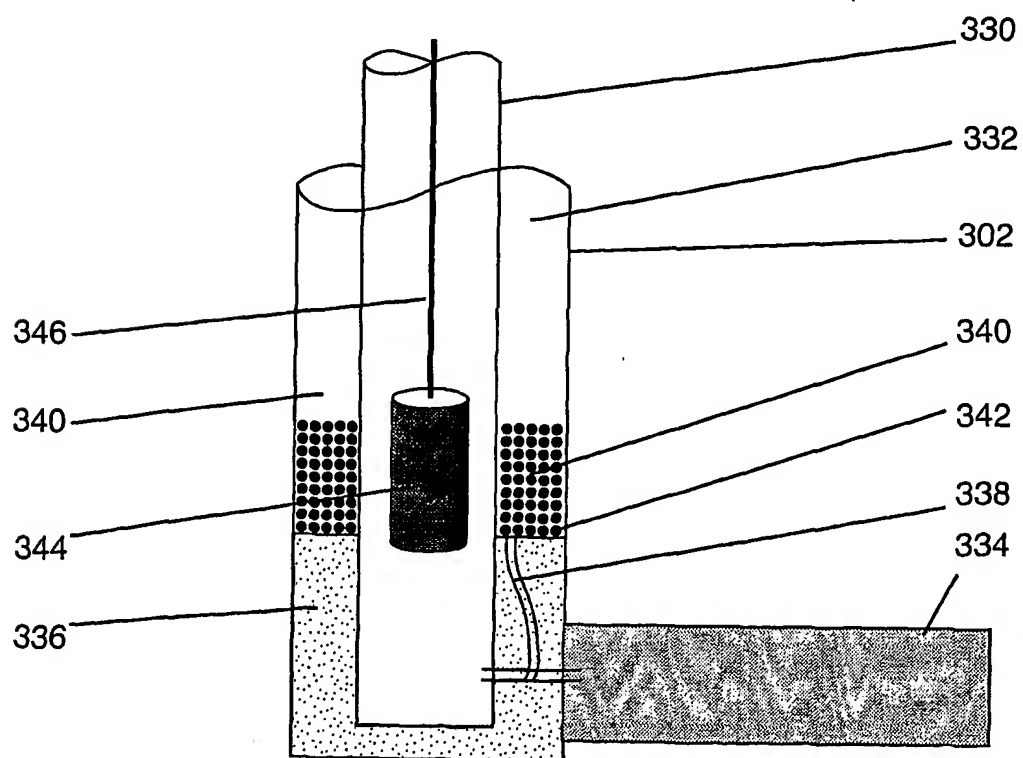


Fig. 5

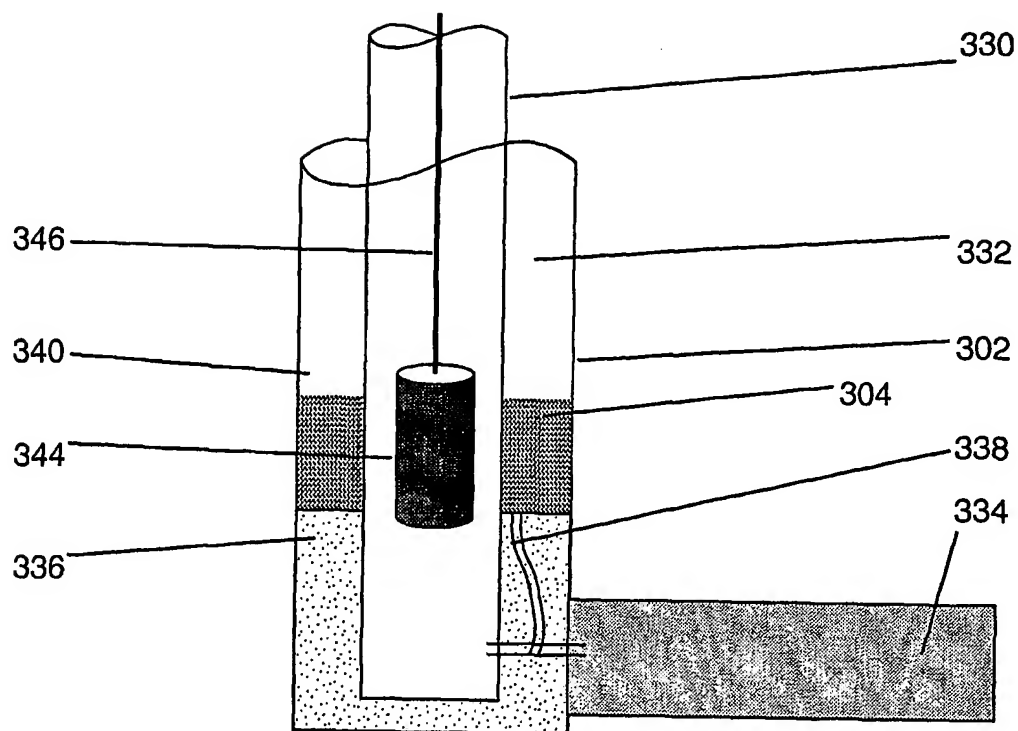


Fig. 6

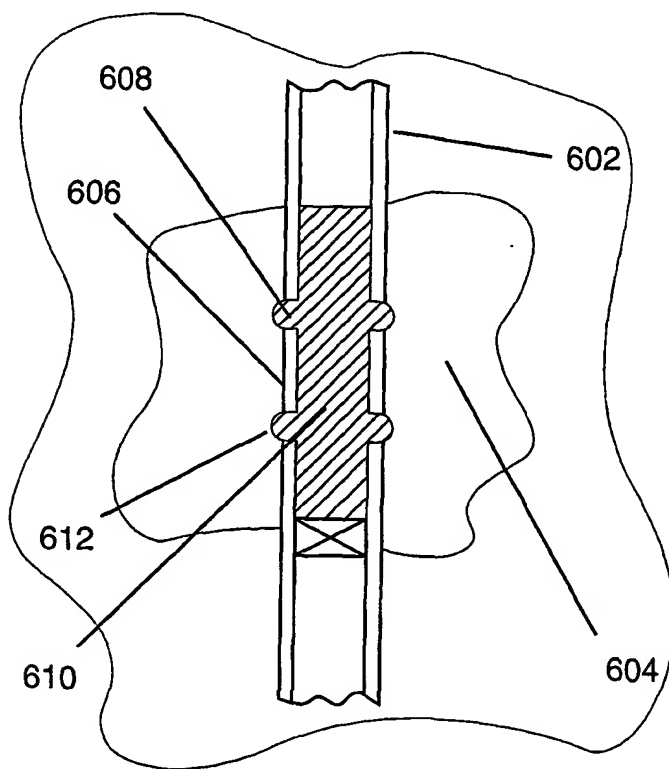


Fig. 7

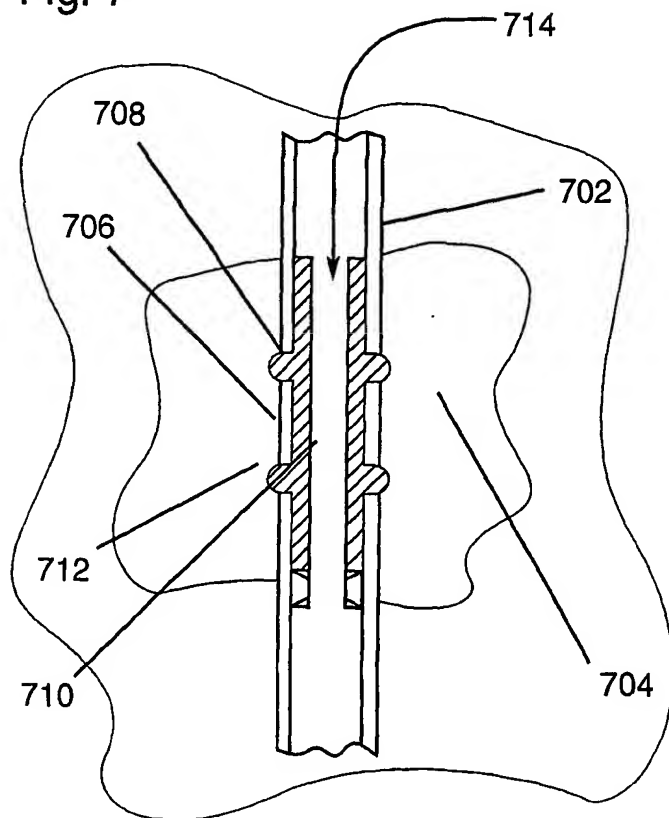
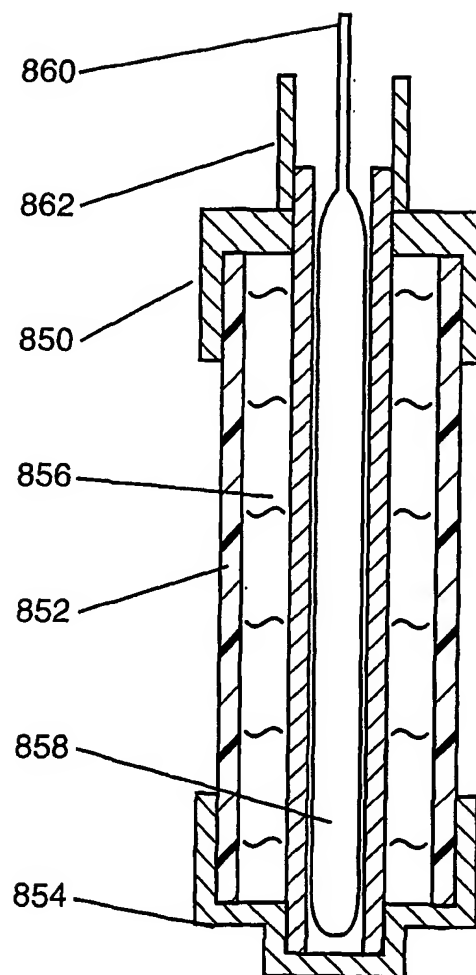


Fig. 8



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/07486

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) :F16L 55/10

US CL :138/89

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 138/89, 90, 97, 98, 142; 166/250.04, 386, 116, 121, 122, 127, 131, 135, 192

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST search terms: braze, solder, bismuth, molten metal, perforated, holes, steel, heating element, rubber, elastomer, plug

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 4,612,959 A (COSTELLO) 23 September 1986, see entire document.	1-3, 11-15 ----- 4, 5, 16, 21-25
Y	US 1,921,809 A (CRAIN) 08 August 1933, see entire document.	4
X -- Y	US 3,996,100 A (OGUMA et al) 07 December 1976, see entire document.	1, 11-18 ----- 2-8, 10, 16, 21-25
A	US 3,697,377 A (GAUTHRON) 10 October 1972, see entire document.	1-25
A	US 3,638,730 A (SMITH) 01 February 1972, see entire document.	1-25

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

18 JUNE 2001

Date of mailing of the international search report

02 AUG 2001

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US01/07486

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,963,580 A (ECKERT) 05 October 1999, see entire document.	1-25